HOWREY SIMON ARNOLD & WHITE
HOWREY EUROPE

THE REMBRANDT TOWER, 31ST FLOOR
ONE AMSTELPLEIN
1096 HA AMSTERDAM, THE NETHERLANDS
PHONE: +31 (0) 20 592 4411 • FAX: +31 (0) 20 463 7296

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# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:
Reinders

Serial No. 10/808,342

Confirmation No. 5445

Filed: 25th March 2004

Title: VEHICLE COOLER

Group Art Unit: 3744

Examiner: not assigned

Atty. Dkt. No.: 05589.0020.NPUS00

## INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

Sir,

Listed on accompanying form PTO/SB/08A and/or attached to this IDS are documents that may be considered material to the examination of this application, in compliance with the duty of disclosure requirements of 37 C.F.R. §§ 1.56, 1.97 and 1.98. A copy of non-US patent documents is provided.

It is respectfully requested that the Examiner initial and return a copy of the attached form PTO/SB/08A, and indicate in the official file wrapper of this patent application that the documents have been considered

Where the publication date of a listed document does not provide a month of publication, the year of publication of the listed document is sufficiently earlier than the effective U.S. filing date and any foreign priority date so that the month of publication is not in issue. Applicants have listed publication dates on the attached form PTO/SB/08A based on information presently available to the undersigned. However, the listed publication dates should not be construed as an admission that the information was actually published on the date indicated.

Applicants reserve the right to establish the patentability of the claimed invention over any of the information provided herewith, and/or to prove that this information may not be prior art, and/or to prove that this information may not be enabling for the teachings purportedly offered.

This statement should not be construed as a representation that a search has been made, or that information more material to the examination of the present patent application does not exist. The Examiner is specifically requested not to rely solely on the material submitted herewith. It is further understood that the Examiner will consider information that had been cited by or submitted to the U.S. Patent and Trademark Office in a prior application relied on under 35 U.S.C. § 120. 1138 OG 37, 38 (May 19, 1992).

The following items with checked boxes apply to this Information Disclosure Statement (IDS):

☒ 1. This IDS is being filed within three months of the U.S. filing date or entry of the national stage OR before the mailing date of a first Office Action on the merits. No statement under 37 C.F.R. § 1.97(e) or fee is required.

☐ 2. This IDS is being filed more than three months after the U.S. filing date or entry of the national stage AND after the mailing date of the first Office Action on the merits, but before the mailing date of a Final Rejection or Notice of Allowance.

☐ a. I hereby state that each item of information contained in this IDS was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to filing this IDS. 37 C.F.R. § 1.97(e)(1); or

☐ b. I hereby state that no item of information in this IDS was cited in a communication from a foreign patent office in a counterpart foreign application, and, to my knowledge after making reasonable inquiry, no item of information contained in this IDS was known to any individual designated in 37 C.F.R. § 1.56(c) more than three months prior to filing this IDS. 37 C.F.R. § 1.97(e)(2); or

☐ c. The Commissioner is authorized to charge **Deposit Account No. 08-3038,** referencing the above docket number, in the amount of $180 in payment of the fee under 37 C.F.R. § 1.17(p).

☐ 3. This IDS is being filed more than three months after the U.S. filing date and after the mailing date of a Final Rejection or Notice of Allowance, but before payment of the Issue Fee. It is hereby requested that the IDS be considered. The Commissioner is

authorized to charge **Deposit Account No. 08-3038**, referencing the above docket number, in the amount of $180 in payment of the fee under 37 C.F.R. § 1.17(p).

☐ a. I hereby state that each item of information contained in this IDS was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to filing this IDS. 37 C.F.R. § 1.97(e)(1); or

☐ b. I hereby state that no item of information in this IDS was cited in a communication from a foreign patent office in a counterpart foreign application, and, to my knowledge after making reasonable inquiry, no item of information contained in this IDS was known to any individual designated in 37 C.F.R. § 1.56(c) more than three months prior to filing this IDS. 37 C.F.R. § 1.97(e)(2).

☐ 4. In regard to the relevance of non-English language document(s) listed on the enclosed form:

☐ a. For document(s) bearing Cite Nos. , a discussion is provided in the present specification.

☐ b. For document(s) bearing Cite Nos. , which was/were cited in search report(s) for corresponding foreign application(s), an English language version or translation of relevant portions of the foreign search report(s) is attached.

☐ c. For document(s) bearing Cite Nos. , counterpart application(s) in English is/are provided bearing Cite Nos. .

☐ d. For document(s) bearing Cite Nos. an English language abstract is attached to the document(s).

☐ e. For document(s) bearing Cite Nos. an English language translation will be forwarded as soon as it is available.

☐ f. For document(s) bearing Cite Nos. , a concise explanation of relevance is attached to the document(s).

☐ 5. The Examiner's attention is directed to co-pending Application , which is directed to related technical subject matter. The identification of this Application is not to be construed as a waiver of secrecy as to that application now or upon issuance of the present application as a patent. The Examiner is respectfully requested to consider the cited application and the art cited therein during examination.

☒ 6. Copies of document numbers B3 and B6 on the attached PTO/SB/08A were submitted to the Office on January 25, 2005 without English translations. The documents have been translated and are herein attached.

☐ 7. Additional document(s) that may be considered material to the examination of this application are enclosed in compliance with the duty of disclosure:

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Any extension of time that may be deemed necessary to further the prosecution of this application is hereby requested. The Commissioner is authorized to charge any additional fees which may be required, or credit any overpayment, to **Deposit Account No. 08-3038**, referencing the docket number shown above.

The Examiner is respectfully requested to contact the undersigned by telephone at the number given below in order to resolve any questions.

Respectfully submitted,

David P. Owen
Reg. No. 43,344

Date: April 27, 2005

**Customer No. 32894**
Howrey Simon Arnold & White
2941 Fairview Park Drive, Suite 200
Falls Church, VA 22042
Fax: 202 383-7195

Substitute for form 1449/PTO

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

*(Use as many sheets as necessary)*

Sheet 1 of 2

| Complete if Known | |
|---|---|
| Application Number | 10/808,342 |
| Filing Date | 25 March 2004 |
| First Named Inventor | Reinders, J.A.M. |
| Art Unit | |
| Examiner Name | |
| Attorney Docket Number | 05235.0020.NPUS00 |

## U. S. PATENT DOCUMENTS

| Examiner Initials* | Cite No.[1] | Document Number Number-Kind Code[2] (if known) | Publication Date MM-DD-YYYY | Name of Patentee or Applicant of Cited Document | Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear |
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| Examiner Initials* | Cite No.[1] | Foreign Patent Document Country Code[3] "Number[4] "Kind Code[5] (if known) | Publication Date MM-DD-YYYY | Name of Patentee or Applicant of Cited Document | Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear | T[6] |
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| | B6 | NL 7711149 | 04-17-1979 | Doomernik | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2]See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3]Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4]For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5]Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6]Applicant is to place a check mark here if English language Translation is attached.

Publication number : **BE 1013160A6**
Patent proprietor: **Offringa Dirk Dooitze ; Dutch Trading Center Tiel B.V.**

# Method and device for cooling air

This invention concerns a method and a device for cooling air.

More in particular, it concerns a method with which an efficient cooling can be realized.

To this end, the invention concerns a method for cooling air, characterized in that this cooling is at least realized by directing the air to cool through first channels of a heat exchanger, while in second channels of this heat exchanger an evaporation is realized by wetting the walls of these second channels and in combination therewith directing an airflow through the second channels.

Preferably, at least part of the second airflow is cooled before bringing this airflow into the second channels. In this way, the second airflow can take up more moisture in itself, such that a larger cooling capacity becomes possible.

In practice, it is preferred that the second airflow is at least partially cooled by branching off this flow from the first airflow.

According to a particular embodiment, use is made of a second airflow consisting of two or more partial flows that are supplied to the second channels at different locations. In this way it is prohibited that the air in the second channels exhibit too quickly a too high humidity and hence, that few additional moisture is absorbed for realizing the evaporation. By intermediately producing fresh air in the second channels, a better evaporation effect is obtained.

According to a practical embodiment several partial flows are systematically at different locations branched off from the first channels.

Further it is also preferred that the second airflow in essence is running parallel to the first one in counter current, such that the second airflow may be branched off easier from the second one.

According to a particular embodiment, for the second airflow use is made of at least two partial flows that are preferably separated from each other, respectively a first partial flow, which is branched off before or near the inlet of first channels and which realizes a cooling effect in the first part of the first channels, and a second partial flow, which may also consist in itself of several partial flows, which second partial flow is branched off from the second part of the first channels and/or at the exit thereof and which is used to create a cooling effect in the second part of the first channels. This enables to pursue an optimal cooling, such that in the first channels a cooling up to the wet-bulb temperature is aimed for, while in the second part a dewpoint cooling takes place.

According to another particular feature of the invention, the cooling is implemented in a plate heat exchanger and at least part of the second airflow from the first channels is branched off via direct connections between the compartments that are formed between the plates, and this by means of passages in the plates and/or a mutual space locally at the edge of the plates that are overlooked by both compartments. As a result, the air cooled in the first channels in fed directly into the second channels, such that a heating of the second airflow, before it is fed into the second channels, is excluded. Moreover, the use of two different collectors at least at one side of the plate heat exchanger is excluded.

Another improvement of the invention consist of the fact that said cooling by means of said heat exchanger is combined with a so-called mechanical cooling, more in particular a compression cooling, and preferentially this mechanical cooling is controlled as a function of external parameters. By using the correct control, not only the temperature of the air, but also the humidity can be kept at the desired value, without conducting a special intervention to adjust the humidity. After all, said two coolings complete each other.

Preferably, the compression cooling is switch on to a larger extent as the humidity of the inlet air increases. After all, when the humidity increases, the efficiency of the cooling in the heat exchanger decreases and this can ideally be compensated by putting the mechanical cooling into operation. When the air humidity becomes too low, said heat exchanger, which makes

use of a dewpoint cooling, pays off optimally and the mechanical cooling may be limited or excluded, which further has as the advantage that the supplied air is not dehumidified unnecessarily in the mechanical cooling and hence, automatically, too dry air is excluded.

Preferably, use is made of several compressors, preferably with a different nominal power, such that one or more of these compressors can be respectively switched on or switched off, as a larger or smaller compression cooling is desired.

More preferably, one or more compressors with an adjustable power are to be used, preferably by means of a frequency controller.

By means of the techniques as described above the power of the mechanical cooling can systematically be adjusted as a function of the need thereof.

The invention further concerns a device for the embodiment of said method, characterized in that it consists at least of a heat exchanger with first channels for the air to cool and second channels ; means to wet the walls of the second channels; and means to direct the air to cool through the first channels, as well as to direct an airflow through the second channels.

Specific details of preferred embodiments of this invention are described in the dependent claims, and are also described in the subsequent detailed description.

With the aim to better show the features of the invention, some preferred embodiments of a device according to the invention are described by way of example without any delimiting character, with reference to the accompanying drawings, in which :

Figure 1 schematically shows the device according to the invention ;

Figure 2 schematically shows a more practical structure of the device according to Figure 1;

Figures 3 to 8 schematically show different versions of the device according to the invention ;

Figures 9 to 14 a number of special details show that can be applied in the device according to the invention.

As is schematically depicted in Figure 1, the device 1 according to the invention consists at least of a heat exchanger 2 with first channels 3 and second channels 4 ; means 5 to wet the walls 6 of the second channels 4 ; and not shown means to direct the air to cool in the form of a first airflow 7 through the first channels 3, as well as to direct a second airflow 8 through the second channels 4.

In the example shown the second airflow 8 is branched off from the second airflow 7, after which the latter has left the heat exchanger 2.

The means 5 to wet the walls 6 may be of arbitrary nature, but preferably contain – as indicated in Figure 1 - a supply 9 for a liquid, more in particular water, that is distributed over the walls 6 by means of a nebulizer or the like. As also depicted, these means 5 comprise preferably, but not necessarily, an absorbent layer 10, applied onto the walls 6, to distribute the moisture.

The action of this device 1 relies on the fact that the moisture on the walls 6 is being evaporated and transported by means of the second airflow 8. Because of this, the walls 6 are cooled down, which also brings about a cooling effect in the first channels 3, such that the airflow 7 is cooled down. Because the airflow 8 is branched off from the airflow 7, it is relatively cold and therefore can absorb an optimal amount of moisture.

As is depicted in Figure 2, preferably use is made of a plate heat exchanger, to obtain an optimal heat exchange, such that the first channels 3 are formed by the compartments 11 and the second channels 4 are formed by the compartments 12. The aforementioned layer 10 is hereby applied on the outside of the wall of the compartments 11.

As depicted in Figure 2, preferably use is made of parallel airflows 7 and 8. It is clear that in practice the inlet airflow 7 and the outlet airflow 8 are kept separate from each other.

According to the embodiments of Figures 3 and 4, the second channels 4 are directly branched off from the first channels 3, hence without a special connection conduit being used. In this case, this direct connection consists of a chamber 13 that is located immediately behind the plates of the plate heat exchanger 2, in which the first channels 3 discharge, as well as the

second channels **4** begin. The second airflow **8** is immediately bend back from the first airflow **7**, as is indicated with the numeral **14**.

Figure 3 also shows that the above mentioned means to generate the airflows **7** and **8** may consist of ventilators **15** and **16**, in which the ventilator **15** provides for the inward suction of the overall airflow, while the ventilator **16** provides for the extraction of the airflow **8** from the first airflow **7**.

Provided the device **1** is properly dimensioned, one ventilator **17** is sufficient, which, as depicted in Figure 4, pushes the air for the airflows **7** and **8** through the device **1**.

According to Figure 5, the second airflow **8** is branched off from the first channels **4** by means of at least two branches, in this case several branches **14A** that are situated on different locations according to the direction of the flow in the first channels **3**. Hence, a second airflow **8** is obtained that is composed of different partial flows **8A**, such that the air that is branched off and that is still relatively dry, is better distributed in the second channels **4** and hence, may absorb moisture more optimally.

It is noted that the principle of Figure 5 is not necessarily limited to parallel channels **3** and **4**, but also can be applied in a device **1**, as is depicted schematically in Figure 6, in which channels **3-4** are applied which run crosswise.

In Figure 7 another variant is schematically shown, in which for the second airflow **8** use is made of at least two partial flows **8B** and **8C** that are preferably separated from each other, respectively a first partial flow **8B** that is branched off before or near the inlet of the first channels **3** and which effects a cooling effect in the first part **18** of the first channels **3**, and a second partial flow **8C**, which is branched off from the second part **19** of the first channels **3** and/or at the exit thereof and is used for creating a cooling effect in the second part **19** of the first channels **3**. Hence, the advantages of this specific embodiment, as mentioned in the introduction, are obtained.

It is noted that the partial flow **8C** in itself can also consist of several partial flows, similar to the partial flows **8A** in Figure 5.

Figure 8 schematically shows a special embodiment, in which – apart from said heat exchanger **2** - also a so-called mechanical cooling **20** with at least one compressor is used, preferably two or more compressors, respectively **21** and **22**, as well as a controller **23** that controls the mechanical cooling **20** as a function of external parameters, such as the air humidity. As mentioned in the introduction, this combined device **1**, i.e. the combination of a cooling by means of a heat exchanger **2** as described above, and a mechanical cooling **20**, allows to always search for the most optimal combination.

The two compressors **21-22** have a different nominal power. Furthermore, the controller **23** comprises also a control to adjust the power of the compressors, preferably in a stepless manner, for example by means of a frequency controller.

Hence, it is achieved that exclusively the smallest compressor **21** is put into operation when only a small mechanical cooling is needed. At a higher desired power, exclusively the larger compressor **22** is put into operation. When a still higher power is needed, both compressors **21** and **22** are put into operation in a parallel manner.

For the stepless control, use can be made of a frequency controller.

The mechanical cooling **20** or compression cooling can be obtained with different kinds of compressors **21-22**, both piston compressors as well as screw compressors.

Figures 9 to 14 concern a special detail that can be implemented in the device **1**, such that another remarkable improvement can be realized when a moisture-absorbing and/or hygroscopic layer **10** is applied. This improvement consists in the fact that locally in this layer **10** additional means **24** are provided that promote the dispersion of the moisture in said layer **10**.

These means **24** are preferably embodied in such a way that they provide for a buffer action, i.e., they more or less collect and/or slow down the moisture that runs down the layer **10**, and hence promote a better dispersion by absorption.

According to Figures 9 and 10 these means **24** consist of in essence horizontal ledges **25** that cooperate with said walls **6**, more in particular said layer **10**, more in particular that are

attached thereto. Hence, the flow of moisture **26**, more in particular the water that is running down through the layer **10**, is more or less slowed down and an amount of liquid **27** is collected on the ledges **25**, an amount which is redispersed by absorption. The excess liquid flows over the edge of the respective ledge **25** to the next ledge and also penetrates partially behind the ledge **25** through the layer **10** downwards. In this way dry spots are formed in the layer **10**.

Figures 11 and 12 show a variant, in which the ledges **25** are provided with oblique passages **28**. In these, droplets **29** are retained, such that a uniform dispersion is also promoted. The water droplets **29** also form a horizontal conduction for the airflow **8**.

Figure 13 shows an embodiment in which the ledges **25** extend over the full width of the channels **4**, however in which passages **30** in these ledges **25** have been formed.

However, as depicted in Figure 14, it is not excluded to implement the ledges **25** as completely closed, such that on each ledge **25** an amount of liquid **27** can be collected that subsequently may penetrate further downwards through the layer **10**. Hence, at each level where there is a ledge **25** present, a redistribution of the liquid is foreseen over the total length of the second channels **4**.

The present invention is by no means delimited to the embodiments as described in the examples and as shown in the figures, however, such method and device may be implemented according to different variants without going beyond the scope of the invention.

Claims

1. Method for cooling air, characterized in that this cooling is at least realized by directing the air to cool through first channels (3) of a heat exchanger (2), while in second channels (4) of this heat exchanger (2) an evaporation is realized by wetting the walls (6) of these second channels (4) and in combination therewith directing an airflow (8) through the second channels (8).

2. Method according to claim 1, characterized in that at least part of the second airflow (8) is cooled before bringing this airflow into the second channels (4).

3. Method according to claim 2, characterized in that the second airflow (8) is cooled by branching off this flow from the first airflow (7).

4. Method according to claim 2, characterized in that the second airflow (8) consists of two or more partial flows (8A) that are supplied to the second channels (4) at different locations.

5. Method according to claim 4, characterized in that the partial flows (8A) are branched off from the first airflow (7) at different locations, such that at least one location is situated between the inlet and outlet of the first channels (3).

6. Method according to claim 5, characterized in that the partial flows (8A) are systematically branched off from the first channels (3) at different consecutive locations.

7. Method according to any one of the preceding claims, characterized in that the second airflow (8) is oriented in essence parallel to the first airflow (7) in counter current.

8. Method according to any one of the preceding claims, characterized in that for the second airflow (8) use is made of at least two partial flows (8B - 8C) that are preferably separated from each other, respectively a first partial flow (8B) that is branched off before or near the inlet of the first channels (3) and which effects a cooling effect in the first part (18) of the first channels (3), and a second partial flow

(8C), which in itself can also consist of several partial flows (8A), such that this second partial flow (8C) is branched off from the second part (19) of the first channels (3) and/or at the exit thereof and is used for creating a cooling effect in the second part (19) of the first channels (3).

9. Method according to any one of the preceding claims, characterized in that it is implemented in a plate heat exchanger (2) and at least part of the second airflow (8) from the first airflow (7) is branched off via direct connections between the compartments (11-12) that are formed between the plates, and this by means of passages in the plates and/or a mutual space or chamber (13) locally at the edge of the plates that are overlooked by both compartments (11-12).

10. Method according to any one of the preceding claims, characterized in that said cooling is combined with a so-called mechanical cooling or compression cooling (20).

11. Method according to claim 10, characterized in that the compression cooling (20) is controlled as a function of external parameters.

12. Method according to claim 11, characterized in that the compression cooling (20) is switch on to a larger extent as the humidity of the inlet air increases.

13. Method according to any one of the claims 10 to 12, characterized in that use is made of several compressors (21-22), preferably with a different nominal power, such that one or more of these compressors (21-22) can be respectively switched on or switched off, as a larger or smaller compression cooling (20) is desired.

14. Method according to any one of the claims 10 to 13, characterized in that use is made of compressors (21-22) with an adjustable power, preferably by means of a frequency controller.

15. Device for cooling air, for the embodiment of the method according to any one of the preceding claims, characterized in that it consists at least of a heat exchanger (2) with first channels (3) for the air to cool and second channels (4) ; means (5) to wet the

walls (6) of the second channels (4) ; and means to direct the air to cool through the first channels (1), as well as to direct an airflow (8) through the second channels (4).

16. Device according to claim 15, applying the method according to any one of the claims 4 to 6, characterized in that the airflow (8) in the second channels (4) is branched off from the first channels (3) by means of at least two branches that are situated on different locations according to the direction of the flow in the first channels (3).

17. Device according to claim 15, applying the method according to claims 9, characterized in that the heat exchanger (2) consists of a plate heat exchanger in which the second channels (4) run at least partially in counter-current relative to the first channels (3) and in which these second channels (4) are directly connected to the first channels (3) with the aim to branch off the second airflow (8) from the first airflow (7).

18. Device according to claim 17, characterized in that the direct connection at least consists of a chamber (13) that is located immediately behind the plates of the plate heat exchanger (2), in which the first channels (3) discharge, as well as the second channels (4) begin.

19. Device according to any one of claims 15 to 18, characterized in that the heat exchanger (2) consists of a plate heat exchanger in which the walls (6) of the second channels (4) are provided with a moisture-absorbing and/or hygroscopic layer (10) and that locally in this layer (10) additional means (24) are provided that promote the dispersion of the moisture in said layer (10).

20. Device according to claim 19, characterized in that these means (24) consist of buffers or the like, formed by one or more of the following elements :

- one or more in essence horizontal ledges (25) that cooperate with said walls (6);
- one or more in essence horizontal ledges (25) that cooperate with said walls (6) and that are provided with passages (28-30) ;
- one or more in essence horizontal ledges (25) that extend over the full width, i.e. between two walls (6) of the second channels (4).

21. Device according to any one of claims 15 to 20, characterized in that it contains, besides said heat exchanger (2) also a so-called mechanical cooling (20) with at least one compressor (21-22), as well as a controller (23) that controls at least the mechanical cooling (20) as a function of external parameters, such as the air humidity.

22. Device according to claim 21, characterized in that the mechanical cooling (20) contains at least two compressors (21-22) with a different nominal power, as well as a controller (23) to switch on these compressors (21-22) as a function of the need thereof, as well as to change the power thereof.

**Figures**

Figures 1 to 14 : are identical to publication. No translation is provided.

Publication number : NL 7711149
Applicant : Cornelis Doomernik

# Method and device to cool an airflow

The invention is concerned with a method and a device to cool an airflow, for example as part of an air conditioning device.

With the usual air conditionings, a flow of used air is continuously removed to the outside and replaced by a flow of freshly supplied outside air of the same amount. During warm periods this freshly supplied air is cooled down before it is admitted to the building, for example to an inlet temperature of 16 °C.

This cooling down takes place with the common devices mainly using a compression cooling machine or using an absorption cooling device. Because this uses a lot of electrical energy, sometimes a pre-cooling is applied, in which the air that is supplied from the outside is pre-cooled in an indirect heat exchanger with the cooler removed air.

In Klima und Kalte Ingenieur 5/1977, page 239-242, an improvement of such a pre-cooling is shown, in which the air to remove for this heat exchange is first cooled down by nebulizing water in it, which subsequently partly evaporates. By this evaporation, said air to remove is cooled down, preferably to its wet-bulb temperature, and this cooled air is subsequently used for the pre-cooling of the fresh air. By this, the pre-cooling becomes much more effective, such that less energy is needed in the compression cooler. This energy saving may amount up to 38 %.

According to the invention an airflow is cooled down by indirect heat exchange in counter current with a second airflow, which second flow is cooled by evaporating water in it and the method is characterized in that the first flow, immediately after it has been cooled down by heat exchange, is divided into a first part that is used as a second flow, while water is being evaporated in it, and into a second part that is being removed as cooled air.

By the evaporation of water, the second airflow is cooled down to about its wet-bulb temperature. However, this wet-bulb temperature is for the cooled air considerably lower than for the same air before this air is cooled down, and therefore the first flow undergoes a heat exchange with a considerably colder airflow than with said method from Klima und Kälte Ingenieur, and the consequence is that the first flow according to the invention can be cooled down to a considerably lower temperature than with said known method.

In this manner it is possible to cool down the first flow to close above its dewpoint, irrespective of what the starting temperature of the first flow was.

In the drawing is shown :

Fig. 1 is a schematic representation of an embodiment of the device according to the method ;

Fig. 2 is a graph that shows the development of the temperature and the humidity level in an example of the method according to the invention in a device according to Fig. 1.

Fig. 3 and Fig. 4 are graphs that show the development of the temperature and the humidity level in an example of the method according to the invention in a device according to Fig. 5.

Fig. 5 is a schematic representation of a device according to the invention for air conditioning.

In Fig.1 is shown a simple embodiment of a device to perform the method according to the invention. At **1**, the first flow is supplied, for example freshly supplied air from the outside, which needs to be cooled. This air is led through the heat exchanger **2** and cooled down. Arrived at the left end **3** of the heat exchanger **2**, the first flow is split into a part that is transported by ventilator **4** as cooled air, and a part that is transported back to the heat exchanger **2** as a second flow by the valve **5** and the ventilator **7**. Before this flow is led through the channels of the heat exchanger, this air is moisturized by nebulizing water in it using the nebulizer **8**. Preferably, such an amount of water is nebulized, that the second flow is completely saturated with water and furthermore still an amount of water that is not vaporized remains in the form of a fine mist. By the heat exchange the temperature of the second flow rises and hence, a new amount of water may evaporate, such that the suspended droplets are converted slowly into water. This further evaporation of water has as a consequence that the temperature of the second flow rises less quickly than would be the case without these suspended droplets and the temperature difference between the second flow and the first flow thus rises in the drawing from the left to the right.

Because a part of the droplets settles before they may evaporate completely and because the total amount of water that can be suspended in the air as fine droplets, is limited, as a rule, all droplets will be disappeared before the right end of the heat exchanger is reached. Therefore, according to a preferred embodiment of the invention in the second flow, at at least one point between the ends of the heat exchanger, once again water is nebulized into the second flow. In Fig. 1 only two of such nebulizing devices **8** and **8'** are indicated, but it is clear that this number may be increased as the need exists. These sprinklers or nebulizers can be of any known type, but they are preferably chosen such that a part of the water that is as large as possible is dispersed as a very fine mist.

After the second flow has passed through the entire heat exchanger, it is removed by the drip catcher **9**, which catches a large part of the suspended droplets that are still present and which transports these droplets downwards.

Beneath the heat exchanger **2** a collector **10** is placed, in which all water is collected that settles from the second flow and from the mist filter. This water is transported back to the nebulizers **8** and **8'** by pump **12** and conduit **13**. The level in the container **10** is kept constant by supplying water at **11**, which is regulated by a float.

During warm periods, in which there is a need for cooling, the valve **6** in this device is kept closed and the valve **5** is kept open. During cold periods, in which there is no need for cooling, but there is a need to avoid the loss of heat with the ventilation air, the valve **5** is closed and valve **6** is opened. Furthermore, the nebulizers are not used. Hence, the air to be removed to the outside, enters in a known manner into indirect heat exchange with the air supplied from the outside, such that the fresh air is preheated and the used air is removed at about the temperature of the outside air. Hence, the device of Fig. 1 may also be used as a recycler.

Because the exchange surface is contacted with the evaporating water, it is possible that depositions thereon may occur. To prevent such, according to a preferred embodiment, these surfaces are manufactured of or coated with a material that is water-repellent, such that on this a closed film of water cannot be formed. Moreover, such a film would form an extra barrier for the heat flow, such that a water-repellent material is also useful in this respect. Surfaces,

manufactured from polyalkenes, such as polyalkene or polypropene or from impact-resistant polystyrene (ABC resin) appear to be very suitable and also relatively cheap.

The operation of the device according to Fig. 1 is explained in Fig. 2, which represents an i-x diagram (i=enthalpy and x=amount of water).

In this graph the temperature of the air (dry-bulb temperature) is as plotted on the right-hand scale. The upper abscissa scale shows the amount of water a partial water vapour pressure in mbar and the lower abscissa scale the amount of water as kg water per kg dry air.

The graph further shows straight diagonal lines that connect states with equal enthalpy and the enthalpy values are plotted on the diagonal scale at the right-bottom side. Also, in the graph are drawn the curves that connect the points with equal relative humidity, for example a relative humidity of 30 %.

When the state of the outside air that is supplied to the heat exchanger at 1 as a first flow, is indicated by point A (+32 °C, 0.011 kg water/kg dry air), then the wet-bulb temperature of that air is found by drawing a line through A, parallel to the lines for constant enthalpy up to the line of saturation. Hence, the wet-bulb temperature is given by point B and lies at about 21 °C.

The Fig. 2, 3 and 4 are drawn in such a way, that the isenthalps are straight and parallel lines. Because of this, it was not possible anymore also to draw all the isotherms horizontally (hence for equal dry-bulb temperature). When one should cool down air by evaporating water in it, starting in point A, until that air is saturated, one could not go below 21 °C and when one subsequently should use that saturated air to cool down another amount of air starting in A, one could not go beyond a temperature close above 21 °C.

However, according to the invention, starting in point A, air is cooled down first by indirect heat exchange to for example 17.5 °C. With this, the absolute level of moisture in the air does not change and hence one arrives in point C. At this temperature, a part, for example half, of the air is removed and the other half is further cooled down by evaporating water into it. With this, the state point of this second part shifts to point D with a temperature of about 16 °C.

Therefore, by the cooling in the heat exchanger, followed by the evaporation of water, a considerably lower temperature has been obtained than with direct wetting, and only by this it is possible to cool down the first flow to point C.

With the cooling down of the first flow, the enthalpy of that flow has decreased with 3.4 kcal/kg. Therefore, it is necessary that the enthalpy of the second flow (when it consists of precisely half of the first flow) increases with 2 x 3.4 = 6.8 kcal/kg. When the second flow is continuously kept saturated with water vapour, the point that reflects the state of this second flow, moves during the heat exchange along the curve DBE and the end state is the point E.

It is evident that this heat exchange is only possible when the temperature in D is lower than in C and therefore it is not possible to cool down the first flow with this heat exchange up to his dewpoint F, but only to a slightly higher temperature. As the point C closes in on the dewpoint F, the temperature difference between C and D that drives the heat transfer in heat exchanger, becomes also smaller and hence a correspondingly larger exchange surface is needed to transfer the necessary amount of heat.

In practice, a temperature difference between C and D of 1-4 °C and preferably of 1-2 °C appears to be still possible at acceptable dimensions of the heat exchanger. In that case the first flow is cooled down to 2-6 and preferably 2-3 °C above its dewpoint.

From the graph, it also shows that the dewpoint F is all the lower, the more point A lies more to the left and hence the absolute humidity of the air is smaller. Therefore, a lower temperature can be achieved, the more the water level in the air is smaller. Moreover, it does not matter what the initial temperature of that air is, because one will arrive in C upon cooling from a point directly above or directly beneath A. The only difference is that the point E will progress further or less further along the saturation curve to the right because then more or less water must be evaporated.

When because of very dry outside air the temperature of C becomes lower than desired, for example lower than 16 °C, the cooling can be decreased by evaporating less water into the second flow, for example by switching off one or more nebulizers 8' or by reducing the part of the first flow that is transported back as the second flow. However, when because of a

large absolute humidity, point C cannot have a low temperature, as is desired, then the desired temperature can still be achieved by still further cooling down the air that is removed by C, for example using a compression cooling device or absorption cooling device. Also, with this, water will also be condensed.

Another method is to remove from the first flow a part of his humidity level before said flow is cooled down, for example by spraying in it a concentrated solution of lithium chloride (which subsequently needs to be regenerated) or with a regenerative rotating air dryer. By this, the dewpoint is lowered.

Anyway, in The Netherlands and in many other part of the world, only rarely circumstances occur in which the absolute humidity of the air is larger than 0.010 kg water per kg dry air, such that one can also content oneself that during a limited number of hours per year, the outlet temperature of the device is slightly higher than 16 °C.

The device according to the invention may be implemented in an air conditioning device in several ways.

One may only cool the freshly supplied air and supply it to the building and remove a corresponding amount of used air simply to the outside.

However, it is more favourable to cool down a flow of air that is to be removed from the building, use part of it to cool down the first flow of used air by evaporation of water, and transport this part back to the building. This provides an extra amount of cooling.

However, still more favourable is a device as schematically shown in Fig. 5, because this can be combined very effectively with a compression or absorption cooling device or with another usual cooling device, which extra cooling device only needs to be used when it is needed. This cooling device removes at once a part of the water vapour present in the air.

In Fig. 5,return air is transported at 1 from the building and this air is supplied at 22 to an indirect heat exchanger 23 and cooled down there in the same manner as in Fig. 1. The cooled air is divided at 24 into two parts. The first part is returned at 25 as cooling agent, humidified by the nebulizers 26 and 26' and after heat exchange removed at 27.

The second part of the air to remove that was already cooled, is removed by the conduit **31**, humidified with nebulizers **32** and **32'** and used as cooling agent in a second heat exchanger **35**, in which the freshly supplied outside air is cooled. This fresh air is supplied at **34** and removed at **36**. The drawing schematically shows also a compression cooling device **17**, which can be switched on when the cooling in the heat exchanger 35 is deemed to be insufficient. The heat exchangers **23** and **35** are each provided with a container **28** with a water supply **29** and with a water pump **30** to transport water to the nebulizers.

For example, one may supply at **1** 10,000 kg/hr air at 25 °C and at an absolute humidity of 0.0087 kg water/kg air. This is subsequently cooled in the heat exchanger **23** to 14.5 °C. Of this 10,000 kg/hr, 5,000 kg/hr is saturated with water by the nebulizers **26** and **26'** (such that the temperature drops to 13 °C) and used to cool down the 10,000 kg/hr air to remove. This 5,000 kg/hr is subsequently at **27** removed at a temperature of 20 °C. The remaining 5,000 kg/hr is transported by a conduit **27** to a second heat exchanger and after humidification (such that the temperature drops to 13 °C) and heat exchange at **28** removed at 24 °C.

At 34 10,000 kg/hr of air is supplied at 30 °C and with a water content of 0.015 kg/kg air. This air has a dewpoint of 20.2 °C and is cooled in the heat exchanger to 17.8 °C, in which at the same time some water condenses. This air, cooled down to 17.8 °C is further cooled down by the compression cooling device to 12 °C, while an extra amount of water condenses. Afterwards, the water content is about 0.0084 kg water per kg dry air.

From the supplied air an enthalpy has been withdrawn of 8.0 kcal/kg, of which 4.2 kcal/kg in the heat exchanger **15** and 3.8 kcal/kg in the compression cooling device **37**. Therefore, well over 52 % of the heat has been withdrawn in the heat exchanger **35**.

In this example a case has been described, in which it was assumed that from outside air with a high moisture content in the outside air a considerably larger part of the total cooling can be obtained in the heat exchanger **35**. At an air humidity of up to 0.0075 kg water/kg dry air, it is even possible to achieve a temperature of 12 °C without any use of a compression cooling device.

Fig. 3 shows the state changes of the air in the heat exchanger **23** from Fig.5 and Fig. 4 shows the changes in the heat exchanger **35** from Fig.5.

Point A is the state of the air to remove at **21** in Fig. 5, B is the state at **24, 25** and **31** in Fig. 5, C is the state immediately after the first nebulizer **36**, respectively **32** in Figure 5, D is the state at point **27**, E that at point **33**, F that at point **34**, G that at point **36** and H that at point **38** in Fig. 5.

The apparatus depicted in Fig. 5 can also be used in cold periods as recycler by redirecting the different airflows, more in particular according to the dotted lines in said figure, while then of course the nebulizers are switched off. During these cold periods half of the freshly supplied air is supplied by each of the heat exchangers and this air is being heated there by heat exchange with the removed and used air.

The energy consumption of a compression cooling device is proportional to the number of hours the device is working, multiplied by the number of degrees C that the air must be cooled down by said cooling device. This product is designated as the cooling degree hours. This concept is defined in Recknagel-Sprengler, Taschenbuch für Heizung und Klimatechnik R. Oldenburg München, Wien (1974).

When the entire cooling is implemented with a compression cooling device using a recycler and is always kept at an inlet temperature of 16 °C of 8,99 hrs to 20,00 hrs, then for a complete year about 7,500 cooling degrees hours are needed.

Under the same circumstances, but with a cooling device according to Fig. 5 and when dividing the air to remove in two equal parts, only 120 cooling degree hours per year are needed. Thus, the number of cooling degree hours of the compression cooling device is only about 8 % of the number without the device according to the invention.

Because said compression cooling device according to the invention is only to cool air that is nearly saturated with water vapour, because of the condensation heat, the cooling energy needed is larger than for the cooling of air that is not saturated with water vapour. Hence, the energy consumption is larger than 8 % of this without the invention, i.e. 15-20 %. Hence, this saving is considerable.

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This is because, on the one hand a very intensive pre-cooling is applied, and on the other hand during the largest part of the year the compression cooling device does not need to be activated.

The remaining energy costs that are necessary to supply fresh air from the outside and to remove used air to the outside by a recycler, also arise with the method according to the invention and are about as large as with the known methods. However, these energy costs constitute for the known method a rather small part of the total energy costs, while they constitute with the method according to the invention a relatively large part and sometimes even the complete energy costs, i.e. then, when a compression cooling device is entirely abandoned.

## Claims

1. Method to cool down an airflow by indirect heat exchange in counter current with a second airflow, which second flow is cooled by evaporating water in it, characterized in that the first flow, immediately after it has been cooled down by heat exchange, is divided into a first part that is used as a second flow, while water is being evaporated in it, and into a second part that is being removed as cooled air.

2. Method according to claim 1, characterized in that water is nebulized into the second flow before said flow enters the heat exchanger, while this nebulizing is repeated at least once during the heat exchange.

3. Method according to claim 1 or 2, characterized in that the supply of water to the second flow is arranged such that the second flow contains a mist of fine droplets in at least the largest part of the heat exchanger.

4. Method according to claim 1 or 2, characterized in that the first flow is cooled down to a temperature that is 2-5 °C higher than its dewpoint.

5. Method according to claims 1-4, characterized in that the second flow comprises 40 - 60 % of the first flow.

6. Method for air conditioning at least a part of a building, in which the air that is to be removed to the outside as a first flow, is cooled down with the method according to claims 1-5 by indirect heat exchange in counter current with a second flow, in which water is being evaporated, which second flow is obtained by dividing the first flow, after it has been cooled down, into a first part, which forms the second flow, and a second part, which is being used as a third flow to cool a fourth flow of air that is supplied from the outside by indirect heat exchange in counter current, while in that third flow, before and during said heat exchange, water is being evaporated.

7. Method according to claim 6, characterized in that water is being nebulized in the second and the third flow before these flows enter the respective heat exchangers, while this nebulizing during the heat exchange is repeated at least once.

8. Method according to claim 6 or 7, characterized in that the supply of water to the second and to the third flow is arranged such that these flows contain a mist of fine droplets in at least the largest part of the heat exchanger.

9. Device to cool a first airflow, which device is provided with an indirect heat exchanger, with a booster and conduits to transport the first flow through the heat exchanger, with a booster and conduits to transport a second airflow through said heat exchanger in indirect heat exchanging contact and in counter current with the first flow, and with at least a nebulizer to nebulize water into said second flow immediately before the supply point of said second flow to the heat exchanger, characterized in that the supply conduit for the second flow is a branch of the supply conduit for the first flow close to the exit site of the first flow from the heat exchanger, while the device is provided with means to regulate the volume ratio of the first and the second flow.

10. Device according to claim 9, characterized in that the device is further provided with at least a nebulizer to nebulize water into the second flow at at least a point situated between the supply point for the second flow towards its removal point from the heat exchanger.

11. Device for air conditioning, which is provided with a device according to claims 9-10 to remove an airflow to the outside while cooling, characterized in that it is also provided with conduits to transport the part that is not branched off from the first flow to a second heat exchanger, with at least a nebulizer to nebulize water in this remaining part and transport this part through the heat exchanger in indirect heat exchanging contact with a third flow of air that is supplied from the outside.

12. Device according to claim 11, characterized in that it is further provided with a usual compression cooling device to further cool down the cooled air from the second heat exchanger.

**Figures**

Figures 1 to 4 : are identical to publication. No translation is provided.